THE WATER BALANCE OF THE SOIL OF TWO SANDY PLANT COMMUNITIES IN THE IBP SAMPLE AREA OF CSÉVHARASZT

by

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The aim of the examinations begun within the IBP in the Csévharaszt nature conservation area in 1968 was to survey the production-conditions of the natural meadows and rye crops as well as to explore the effect of factors influencing production. The paper of Kovács–Láng – Szabó (1971) reports on the production conditions of the examined meadow communities and on the changes in humidity of their soils, that of Verseghy – Kovács–Láng (1971) discussed lichen production. Kovács–Láng – Szabó (1973) point to the effect of certain environmental factors.

The connection between the vegetation and soils of the conservation area was explored by Simon – Kovács–Láng (1964). According to their examinations, the soil types occurring are *slightly humous sand* – the soil of open and closing sandy meadows, dry sandy oak forests and that of a part of planted acacia groves and black-pine woods. *Brown forest soil with residual carbonate:* the soil of the dry sandy oak forests as well as of the other part of the acacia groves and pine woods. *Rusty-brown forest soil* – develops under the Convallaria oak forests, or rather under their stands mixed with acacia and pine. *Chernozem-like sandy soil:* it is formed under closed sandy meadows upon the effect of vegetation augmenting organic matter. The *meadow forest soil* is the one of poplar groves formed in the place of the original oak–elm woods.

In the present study the author deals with the physical characteristics and water-budget properties of the soils of the two plant communities occurring in the widest areas – Festucetum vaginatae danubiale (a perennial open sandy meadow) and *Convallario-Quercetum roboris danubiale* (Convallaria oak forest).

Material and method

The examinations were conducted on a forest-steppe region of the nature conservation area. The site had been originally a stream-bed of the Danube, with swamp- and moorland vegetation. In the Pleistocene a sand cover was deposited on the original soil. The varying thickness of the sand cover: the micro-relief determines the present distribution of the vegetation. In areas where the sand cover is thick, the level of the groundwater is lower, the water economy of the soil is inadequate: desert steppes have been formed. Where the sand cover is thinner, layers of better water-holding capacity run in the soil near the surface: a forest vegetation could develop. According to the examinations of Szodtfridt and Faragó (1968) in the sandy area of the region between the rivers Danube and Tisza, in places of higher location, on top of sandhills the level of the groundwater is 4 – 5 m, between the hills 1.5 – 2.5 m, in the deeper recesses between the hills 0.5 – 2 m and under the forests 1 – 3 m below the surface. The groundwater level is lowest in the soils of the Festucetum vaginatae community where the higher spring-time water table does not come near the surface by more than 2.5 m even in rather humid years. Thus it is easy to understand that in such places only open meadows can develop.

From all these it appears that forest development in the sand ridges is conditioned on a more favourable water supply. The author's intention was to point this out when she examined the water balance of the open sandy meadows and the *Convallario-Quercetum*, as well as the characteristics of the soil influencing this balance. Her aim was to demonstrate the concrete differences existing in the specific features of water balance.

The open sandy meadow *(Festucetum vaginatae danubiale)* is the most widely occurring plant community in the nature conservation area. 40 – 50% of the soil is covered with floriferous plants, 50 – 60% with cryptogamous ones (moss- and lichén species), or else the soil is bare. The dominant meadow-forming species of the community is *Festuca vaginata*, besides it also *Koeleria glauca* and *Stipa capillata* are significant. Further major representatives of the floriferous plants are *Potentilla arenaria*, *Polygonum arenarium*, *Syrenia cana*, *Minuartia verna*, *Alkanna tinctoria*, *Seseli glaucum* and *Onosma arenaria*. It is characteristic of the community that the ground is covered with mosses and lichens to a high degree. The most frequent species are *Syntrichia ruralis*, *Cladonia furcata*, *Cladonia convoluta* and *Cladonia magyarica*.

The Convallaria oak forest *(Convallario-Quercetum roboris danubiale)* is a community of lower-lying, more fresh soils. In its tree stratum *Quercus robur* is dominant, besides it also *Populus alba* and *Populus tremula* are sporadically met with. Its shrub stratum consists of *Ligustrum vulgare*, *Crataegus monogyna*, *Cornus sanguinea*, *Rhamnus catharticus* and *Berberis vulgaris*. In its herb stratum *Poa nemoralis*, *Brachypodium* *silvaticum*, *Convallaria majalis*, *Polygonatum latifolium*, *Geum urbanum*, *Doronicum hungaricum* and *Calamintha clinopodium* prevail.

The author examined the physical characteristics of the soils – specific weight, bulk density, porosity – according to the standards indicated in the handbooks of methodology (Ballenegger – di Gléria 1962, Szabolcs 1966). The mechanical composition of the soils was determined by the pipetting method. The natural water-holding capacity (= field capacity, W_{field}) and water permeability of the soils were fixed in the field, by the frame soaking method. The subsequent examinations on the water balance of the soils – the determination of capillary water capacity (W_{cap}), maximum moisture storage (W_{max}) as well as hygroscopicity (hy) – were conducted in a laboratory, according to the prescriptions as described in the said methodological handbooks.

Results

The profil descriptions were in every case made at a profile pit. After the profiles had been described, samples for the usual laboratory analysis were taken from each genetic horizon.

The soil of the *open perennial sandy meadow* is slightly humous calcareous sand.

Its soil profile:

Horizon A_0 – the surface of the soil is covered with the 1–2 cm thick litter of the grass species forming the meadow.

Horizon A – is 10 cm thick, slightly humous (with a humus content of 0.3–1.0%), its colour is mid-grey; it is densely interwoven with the roots of the perennial grass species.

Horizon C – to 200 cm below layer "A" a yellow sand layer stretches, practically without humus. The roots of the grass species forming the meadow spread over into this level to a depth of about 40–50 cm.

The profile was explored to a depth of 200 cm, apart from the upper, 30 cm. thick layer the soil was competely homogeneous sand, without any humous level covered up, or a claybank of better water balance. Physically the soil-type is sand throughout. In the profile the fraction of particles exceeding 0.25 mm in diameter predominates, it amounts to 85–90%. (Table I.) As compared with the fractions which can be sedimented, the quantity of fine sand is also considerable: 6–11%. The quantity of the sedimentable parts (the fraction of particles smaller than 0.02 mm in diameter) is represented in an insignificant percentage. Their quantity in the whole profile ranges merely between 2.0–4.8%.

Characteristic of the whole soil profile is a practically uniform mechanical composition; predominant in it is the quantity of the fractions of unfavourable water balance (95%) as against the sedimentable water balance (95%) as against the sedimentable particles which are more favourable in this regard (5%).

The soil of the *Convallario–Quercetum* is a rusty brown forest soil.

Table I.

The textural characteristics of the soil of Festucetum vaginatae

Depth cm	Grain size % (mm diameter)				
	> 0.25	0.25 – 0.05	0.05 – 0.02	0.02 – 0.002	0.002 >
0 – 10	85.2	11.2	1.2	–	2.4
10 – 20	86.8	10.0	0.8	0.4	2.0
20 – 30	88.4	8.8	–	0.4	2.4
30 – 40	90.8	8.8	0.4	–	–
40 – 50	88.4	9.6	–	–	2.0
50 – 60	88.4	9.2	–	2.0	0.4
60 – 70	88.4	9.2	–	–	2.4
70 – 80	83.2	11.6	0.4	4.8	–
80 – 90	89.6	7.6	–	0.8	2.0
90 – 100	90.4	9.2	–	–	0.4
110 – 120	88.4	9.2	–	0.8	1.2
120 – 130	90.8	6.0	–	0.8	2.4
140 – 150	89.6	7.6	0.4	–	2.0

Its spil profile:

Horizon A_{00} – the surface of the soil is covered 3 – 4 cm thick with the litter of the trees and shrubs as well as herbaceous plants.

Horizon A_0 – it is the fermentation layer below the rough litter cover.

Horizon A – a 30 cm thick humous layer. Its upper part (0 – 20 cm) is dark grey in colour, interwoven with the roots of the herbaceous plants of the forest. Its humus content is 3.5%. The lower part of the layer (20 – 30 cm) is of a duller grey colour, the humus content is 0.7%.

Horizon A – B – between 30 and 40 cm; an intermediate layer consisting of pale yellow sand.

Horizon B – extends to 40 – 80 cm in the profile, with iron separated round the roots of the trees owing to which the colour of the layer is reddish brown. The majority of the roots of the trees is to be found in this and in the intermediary level.

Horizon [A] – a covered humous layer strectches in the soil profile to a depth of 80 – 150 cm in level "C". Its colour is dark grey, the humus content is 0.7%.

Horizon D – is the original bedrock upon which the sand layer has settled and where the soil dynamics of the latter has developed. This horizon strectches from 150 cm downwards in the profile, its colour is light grey. The clay content is high, the level is of good water holding capacity.

The author explored the soil of the forest to 200 cm in depth, and still found a clayey layer there.

As regards the percentual distribution of the various grain fractions, the soil profile of the Convallaria oak forest presents much greater diversity than the soil of the meadow (Table II.). In the upper soil layer of 80 cm thickness coarse and fine sand predominate, together they make up *91–97%* as against the *3–9%* of the sedimentable fractions. From 80 cm. downwards the quantity of the sedimentable parts steadily increases in the profile. Parallelly with this the quantity of the sand fractions decreases, especially the fall of the percentage of coarse sand is remarkable. Besides the increase in the silt (or dust) fraction also the clay content is rising within the sedimentable parts. The sudden change in grain composition, to be observed in the profile from 80 cm downwards, considerably modifies the water balance of the soil. The higher silt- and clay content of the lower layers ensures the soil a better water holding capacity and thus enables the formation of a woody vegetation.

Table II.

The textural characteristics of the soil of Convallario-Quercetum

Depth cm	Grain size % (mm diameter)						
	> 0.25	0.25 – 0.05	0.05 – 0.02	0.02 – 0.01	0.01 – 0.005	0.005 – 0.002	0.002 >
0 – 10	56.0	33.1	2.0	3.2	–	2.8	2.8
10 – 20	62.2	32.9	–	1.2	–	1.2	2.4
20 – 30	48.2	47.4	–	–	0.4	1.2	2.8
30 – 40	64.3	31.3	–	0.4	0.8	0.8	2.4
40 – 50	59.4	32.9	–	4.0	–	0.8	2.8
50 – 60	57.4	38.2	1.6	–	0.4	–	2.4
60 – 70	50.0	42.8	–	0.8	–	–	6.4
70 – 80	47.0	47.0	1.6	0.8	0.4	–	3.2
80 – 90	44.4	41.1	2.8	0.8	1.6	1.6	7.7
90 – 100	8.1	60.1	9.7	–	8.5	2.0	11.7
110 – 120	4.5	53.3	12.2	4.5	5.3	2.0	18.3
140 – 150	3.6	38.5	17.0	3.6	8.9	4.5	23.9
150 – 200	3.2	36.8	21.6	15.2	5.2	2.8	11.2

Besides mechanical composition the author also investigated other physical properties of the soils: specific weight, bulk density and the conditions of porosity (Tables III and IV). As well-known, the total porosity of the soils ranges between rather wide limits. It is the sandy soils – as ones without structure – that have the smallest pore volume. Within total porosity the knowledge of *capillary porosity* is essential because a significant part of the water stored in these pores is easily accessible for the plants. The pores smaller than 3 microns in diameter are an exception, since in them the water is firmly bound so that the plants are unable to absorb it with their roots.

Table III.

The physico-mechanical properties of the soil of Festucetum vaginatae

Horizon	Depth cm	Particle density	Bulk density	Total P%	Capillary P%
A	0– 10	2.65	1.50	43.40	25.42
	10– 20	2.65	1.52	42.64	24.01
C_1	20– 30	2.65	1.55	41.50	23.76
	30– 40	2.65	1.60	39.62	21.39
	40– 50	2.65	1.60	37.35	20.25
	50– 60	2.65	1.60	36.98	20.00
C_2	60– 70	2.65	1.60	37.35	20.38
	70– 80	2.65	1.60	36.98	19.52
	80– 90	2.65	1.60	37.35	19.56
C_3	90–100	2.65	1.60	37.35	20.32
	110–120	2.65	1.60	38.49	21.30
C_4	120–130	2.65	1.60	38.11	21.00
	140–150	2.65	1.58	40.37	20.70

According to the porosity of the soils of *Festucetum vaginatae* and *Convallario–Quercetum* the author observed similarities and differences alike. As compared with the lower layers of the soil, the percentages of both total porosity (Total P%) and capillary porosity (Capillary P%) are higher in the upper, 0–40 cm layers of the soils of both communities. Even within this top level, the 20 cm upper layer of the forest soil is conspicuous with a high total- and capillary porosity. In the soil profile of the meadow practically neither total nor capillary P% change from 40 cm downwards. On the other hand, in the soil of the forest porosity increases from 80 cm downwards where a covered humous level and, from 150 cm downwards, already a clayey layer extends. The conditions of porosity of the soil of the two communities are nearly identical in the 40–80 cm layer. This also corresponds with the results of mechanical analysis.

Table IV.

The physico-mechanical properties of the soil of Convallario-Quercetum

Horizon	Depth cm	Particle density	Bulk density	Total P%	Capillary P%
A	0 – 10	2.60	1.17	55.00	40.20
	10 – 20	2.60	1.39	46.53	26.69
	20 – 30	2.60	1.46	43.84	23.17
A – B	30 – 40	2.55	1.49	41.96	20.50
B	40 – 50	2.55	1.56	38.82	19.12
	50 – 60	2.55	1.62	36.47	19.51
	60 – 70	2.55	1.64	35.68	19.37
	70 – 80	2.55	1.60	37.64	20.63
[A]	80 – 90	2.65	1.55	41.50	19.50
	90 – 100	2.65	1.53	42.26	22.00
	110 – 120	2.65	1.52	42.64	20.30
	140 – 150	2.65	1.51	43.40	21.05
D	150 – 200	2.65	1.53	42.64	24.84

The water balance of two soils

The change in water permeability of the soil taken as a function of time differs with the two communities (Fig. 1). In the soil of the *forest* the rate of water permeation decreases from the time when watering was begun until the soil is saturated up to field capacity (W_{field}). From the 220th minute of watering water permeability is constant. Then the quantity of water passing through is 5.10 ml/cm² of soil surface.

The permeability of the soil of the *meadow* changes in a quite contrary direction. The rate of permeation evenly increases until the 150th minute of watering, and seems then to become constant. At that time the quantity of water passing through is 4.50 ml/cm² soil surface. The increasing permeability of the soil of the meadow probably arises from the circumstance that the upper layer of the soil is densely interwoven with the roots of the perennial grass species forming the meadow (Festuca vaginata, Koeleria glauca, Stipa capillata), and in this way the layer retains water for a long time. The said phenomenon is most significant even in case of rain. When this layer of the soil is saturated with water to W_{field} the water runs practically in full through the highly permeable lower level without structure. In the soil of the forest where from 80 cm downwards a layer of better water-holding capacity extends in the profile, the ground saturates up to field capacity in 220 minutes, since the said layer considerably decreases the seepage of water into deeper strata. This is clearly supported also by the fact that no decided outline of soaking can be observed in the soil profile, and to a depth of 200 cm the author could not reach the lower limit of soaking. The soil of the forest was soaked to a depth of 190 cm, layers situated deeper than that only contained the original humidity.

The results of the examinations on water permeability indicate that the soils of both plant communities are highly water permeable as against the loam and clay soils.

The difference in water balance of the two soil-types is shown by the respective data of the Festucetum vaginatae and Convallario-Quercetum soil profiles (Tables V. and VI., Fig. 2. and 3.). The field capacity of the upper 20 cm. level of the forest soil amounts to the two- or threefold of the same layer of the meadow soil. The W_{field} values of the upper 30–30 cm layers are practically identical with the soils of the two communities. Again, the field capacity of layers below 80 cm is considerably different. With the oak-forest the W_{field} value of the lower levels of the soil is the two- or threefold of that in the meadow soil where from 30 cm downwards field capacity is about the same in the profile.

Table V.

Data of the water balance of the soil of Festucetum vaginatae

Depth cm	Moisture content among natural conditions mm	W_{field} mm	W_{cap} mm	W_{max} mm	hy	UW mm	AW mm
0– 10	6.60	7.56	38.13	42.44	0.20	1.20	6.36
10– 20	5.43	7.70	33.00	34.29	0.11	0.67	7.03
20– 30	5.61	6.54	32.83	35.00	0.11	0.68	5.68
30– 40	4.53	6.88	30.22	32.34	0.11	0.70	6.18
40– 50	4.32	6.84	33.61	34.77	0.11	0.73	6.11
50– 60	6.03	7.03	33.40	34.17	0.12	0.80	6.23
60– 70	5.76	7.39	33.83	36.14	0.12	0.80	6.59
70– 80	4.71	7.51	32.60	33.62	0.12	0.80	6.71
80– 90	4.97	8.47	32.47	33.68	0.13	0.86	7.61
90–100	5.11	8.80	33.73	34.71	0.13	0.86	7.94
110–120	6.34	9.96	32.72	34.93	0.13	0.85	9.11
120–130	6.36	10.41	31.57	33.70	0.13	0.85	9.56
140–150	5.86	8.69	31.71	32.18	0.13	0.82	7.87

W_{field} = field capacity, W_{cap} = capillary capacity, W_{max} = maximum moisture storage capacity, UW = unavailable water, AW = available water.

Table VI.

Data of the water balance of the soil of Convallario-Quercetum

Depth cm	Moisture content among natural conditions mm	W_{field} mm	W_{cap} mm	W_{max} mm	hy	UW mm	AW mm
0 – 10	10.33	19.89	47.03	62.01	0.38	1.77	18.12
10 – 20	4.30	14.46	37.09	41.31	0.16	0.88	13.58
20 – 30	5.32	10.95	33.82	42.07	0.13	0.75	10.20
30 – 40	5.06	10.43	30.54	39.15	0.11	0.65	9.78
40 – 50	4.52	10.00	29.82	36.30	0.12	0.74	9.26
50 – 60	4.56	9.88	30.50	35.18	0.10	0.64	9.24
60 – 70	5.57	9.18	31.76	32.52	0.12	0.78	8.40
70 – 80	5.92	14.73	33.00	34.40	0.13	0.83	13.90
80 – 90	6.20	18.00	30.00	31.27	0.23	1.42	16.58
90 – 100	8.36	23.11	33.21	34.25	0.36	2.20	20.91
110 – 120	14.44	27.51	30.85	31.46	0.55	3.34	24.17
140 – 150	16.97	28.70	31.78	32.69	0.35	2.11	26.59
150 – 200	7.50	9.42	37.74	39.74	0.18	1.09	8.33

W_{field} = field capacity, W_{cap} = capillary capacity, W_{max} = maximum moisture storage capacity, UW = unavailable water, AW = available water.

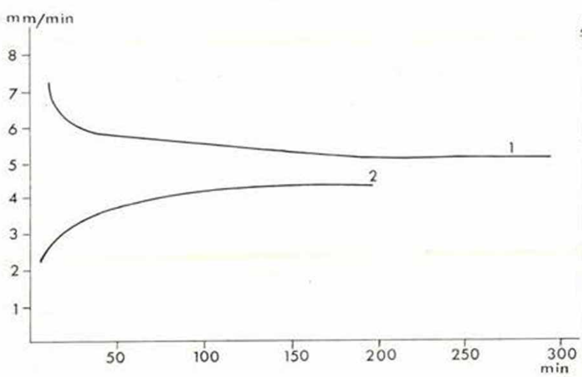

Figure 1. Water-permeability curve of the examined soils. 1 Convallario – Quercetum, 2 Festucetum vaginatae

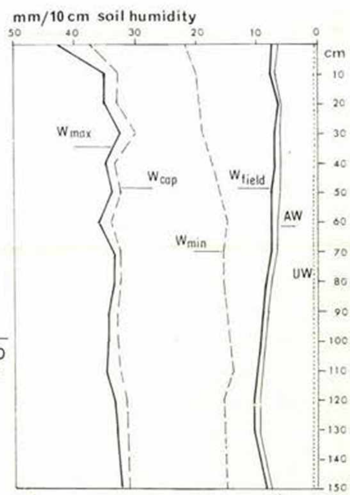

Figure 2. Characteristics of water balance in the soil of Festucetum vaginatae

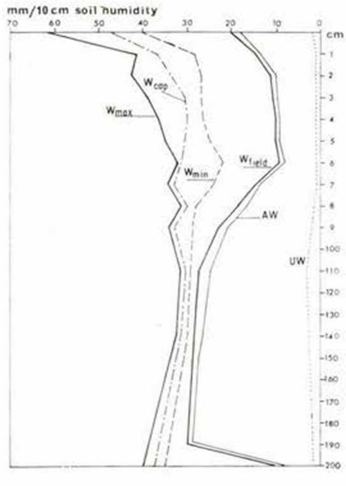

Figure 3. Characteristics of water balance in the soil of Convallario-Quercetum

As to capillary and maximum water capacity, the soils of the two communities present a similar picture, too. The values W_{cap} and W_{max} are highest in the upper 0–30 cm levels of both soil profiles, and change more intensely with depth in the soil of the forest than in that of the meadow. In the level of the oak-forest where the texture of the soil is identical with that of the meadow (from 30 to 80 cm) neither capillary nor maximum water capacity essentially differ from the values obtained in the layers of similar depth of the soil of the latter. On the other hand, the capillary and maximum water capacities of the upper 10 cm layer of the forest soil considerably surpass the water capacity of the upper layer of the meadow.

The differencesin water capicity are caused by the disparity of the mechanical composition of the soils of the two communities, as well as of their physical characteristics. In the Tables and Figures presenting the characteristics of water budget of the two soil, the author also indicated the hy values – as properties clearly expressing the mechanical composition of the soil, as well as the proportion of unavailable water (UW) and available (=disponible) water (AW).

Summary

The author studied the water balance of the soil in two plant communities – Festucetum vaginatae danubiale and Convallario–Quercetum roboris danubiale – to be widely found in the nature conservation area of Csévharaszt. This sandy, wooded-steppe area lies between the rivers Danube and Tisza, and is one of the IBP pattern-plots in Hungary.

The water balance of the soils is determined to a considerable degree by characteristics of soil texture and soil physics. Some difference in physical characteristics, mainly in bulk density and porosity was experienced with the two soil types. The bulk density of the soil of the sandy meadow is between 1.50 and 1.60, that of the forest soil is 1.17 to 1.60. The total porosity of the meadow soil varies between 37% and 44%, that of the forest soil between 36% and 55%. The soils of both associations are of high water permeability: 5.10 ml/min with the forest soil and 4.50 ml/min with that of the meadow per square centimetre of soil surface. There were differences to be observed also in the textural characteristics of the two soils, being especially conspicuous in the deeper layers. In the profile of the forest soil a second, fossiled humous layer extends from 80 to 150 cm, and under it there is a clayey layer. From this the conclusion can be drawn that in the forest soil the sand cover is thin, only 80 cm. The layers under this sand cover have a better water holding capacity so that a forest vegetation can develop. On the other hand, the soil profile of the sandy meadow is completely homogeneous. The sand cover is much thicker than in the forest soil. Also the author's investigations on the water capacity of the soils brought results which corresponded to these findings: the field capacity of the upper layers (0 – 30 cm) and the deeper ones (under 80 cm.) is much higher than that of the same layers of the meadow soil. The same could be experienced at the investigation of capillary and maximum water capacities, as well.

REFERENCES

Ballenegger, R. – di Gléria, J. 1962. Talaj- és trágyavizsgálati módszerek (Methods of Soil and Fertilizer Examination). Budapest.

Di Gléria, J. – Klimes-Szmik, A. – Dvorácsek, I. 1957. Talajfizika és talajkolloidika (Soil Physics and Soil Colloidics). Akadémiai Kiadó, Budapest.

Fekete, Z. – Hargitai, L. – Zsoldos, L. 1964. Talajtan és agrokémia (Soil Science and Agrochemistry). Mezőgazdasági Kiadó, Budapest.

Kovács-Láng, E. – Szabó, M. 1971. Changes of soil-humidity and its correlation to phytomass production in sandy meadow associations. Annales Univ. Sci. Budapest. Sect. Biol. **13**: 115 – 127.

Kovács-Láng, E. – Szabó, M 1973. The Effect of Environmental Factors on the Phytomass Production of Sandy Meadows. Annales Univ. Sci. Budapest Sect. Biol. **15**: 83 – 91.

Simon, T. – Kovács-Láng, E. 1964. Relationship of Plant Communities and Soil Types in the Nature Conservation Area of Csévharaszt. Acta Biol. Acad. Sci. Hung. **6**: 25 – 26.

Stefanovits, P. 1963. Magyarország talajai (The Soils of Hungary). Akadémiai Kiadó, Budapest.

Szodtfridt, I. – Faragó, S. 1968. Talajvíz és vegetáció kapcsolata a Duna – Tisza köze homokterületén (Correlation of Underground Water and Vegetation on the Sandy Area between the Danube and Tisza). Bot. Közl. **55**: 69 – 75.

Szabolcs, I. 1966. Genetikus üzemi talajtérképezés módszerkönyve (Handbook of the Genetic Operative Soil-mapping Methods). OMMI Budapest.

Verseghy, K. – Kovács-Láng, E. 1971. Investigations on the Lichen Productivity in the Sward Communities on Sandy Sites. Acta Biol. Acad. Sci. Hung. **22**: 393 – 411.